Advancing Innovation in Industry

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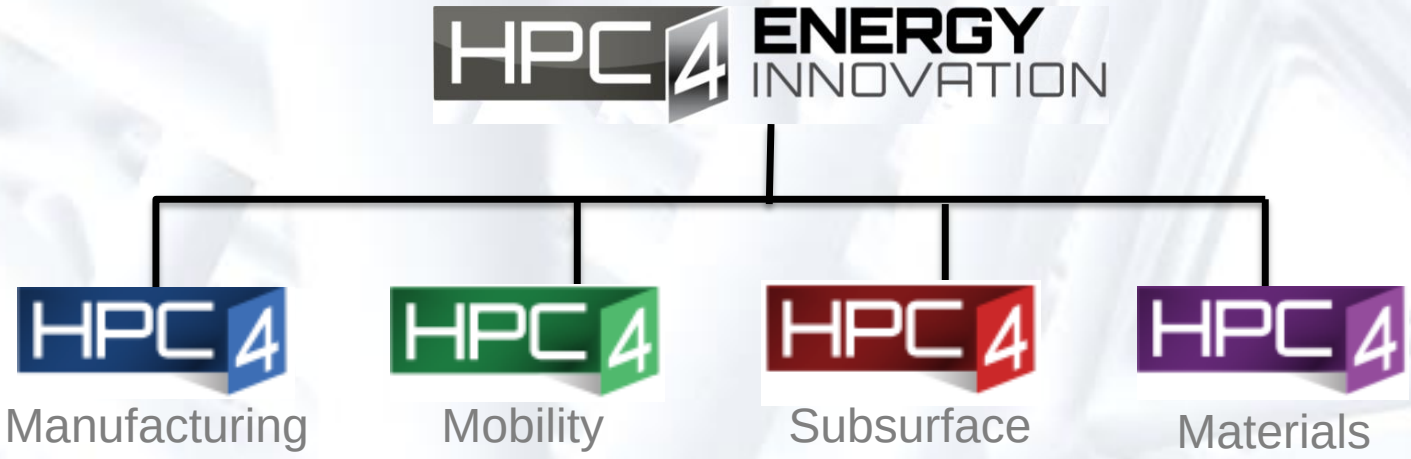
HPC4 MANUFACTURING

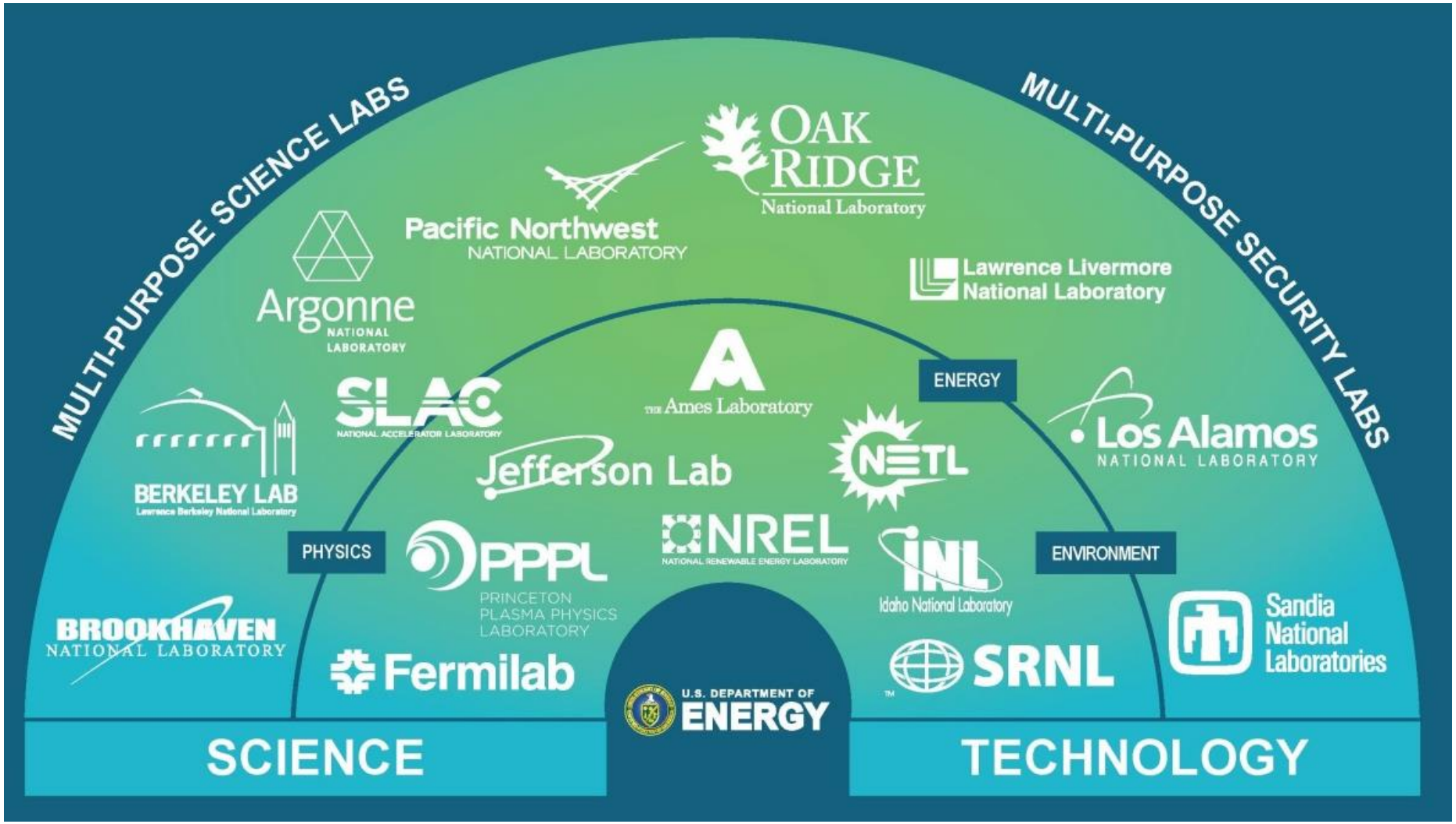
The HPC4Energy Innovation Program has Multiple Pillars



Each aims to apply high performance computing to private sector challenges.
All DOE Labs are eligible to participate.

Overview of Lab Capabilities, Expertise & Hardware

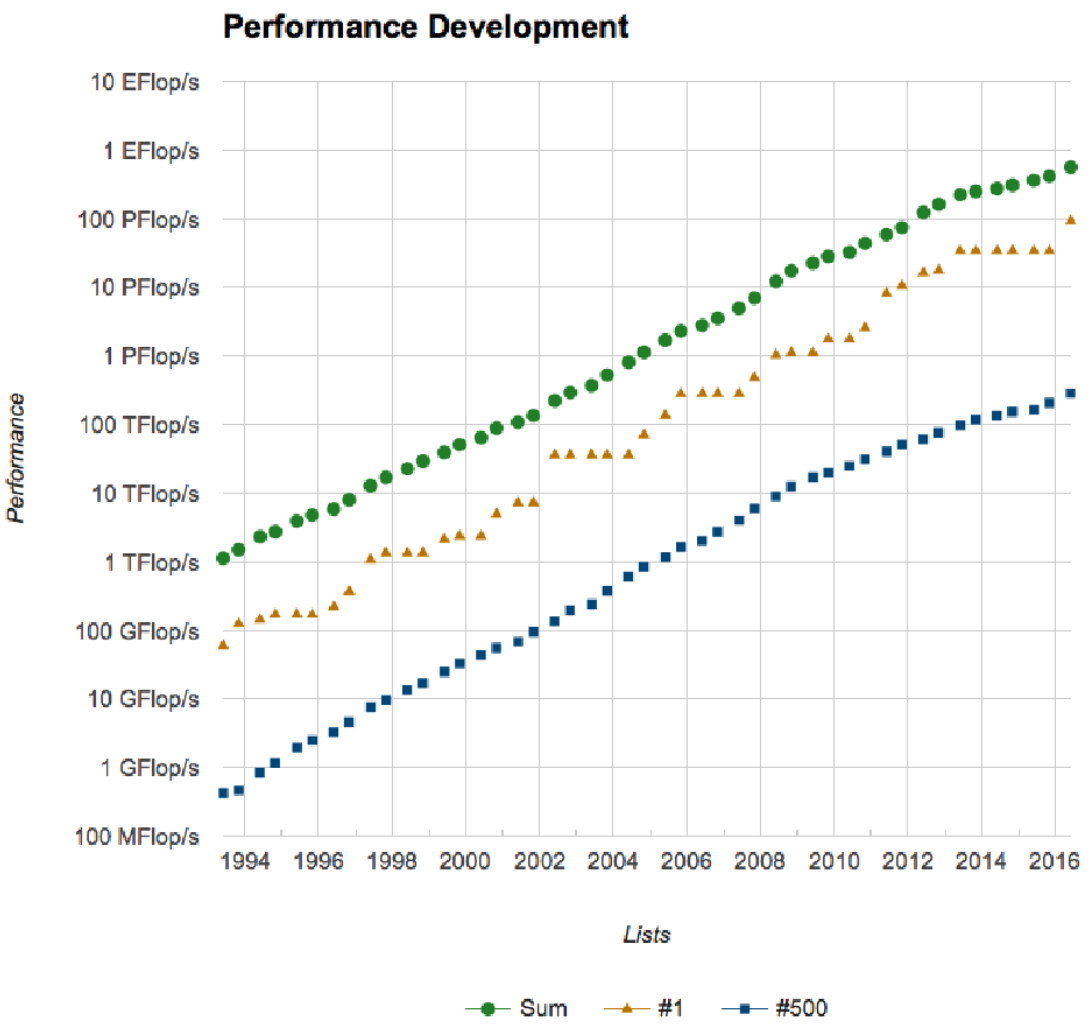
David Skinner, Lawrence Berkeley National Laboratory



HPC4Mfg leverages the vast HPC capabilities at the national labs to partner with industry and address critical challenges

- DOE labs possess 5 of the top 12 HPC systems worldwide and broad expertise in their application: 2 of top 3 in Graph500
- Some larger companies use HPC, but struggle to stay current – few small to medium companies use HPC
- Challenges exist to Industry / National Lab partnerships

This program introduces the power of HPC at low risk to industry.



U.S. DEPARTMENT OF ENERGY | Fossil Energy
OFFICE OF OIL & NATURAL GAS

Lawrence Livermore National Laboratory
BERKELEY LAB
OAK RIDGE National Laboratory
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
ADVANCED MANUFACTURING OFFICE
U.S. DEPARTMENT OF ENERGY | Office of Science

Benefits of HPC to Industry

- Accelerate innovation
- Lower energy costs
- Environmental benefits
- Reduce testing cycles
- Reduce waste/reduce rejected parts
- Quality processes and Pre-qualify
- Optimize design
- Shorten the time to market

These all enhance economic competitiveness

The DOE/International Data Corp. report on HPC: New results indicate high ROI returns resulting from investments in HPC.

On average, from 329 case studies:

$673 in revenue per dollar of HPC invested

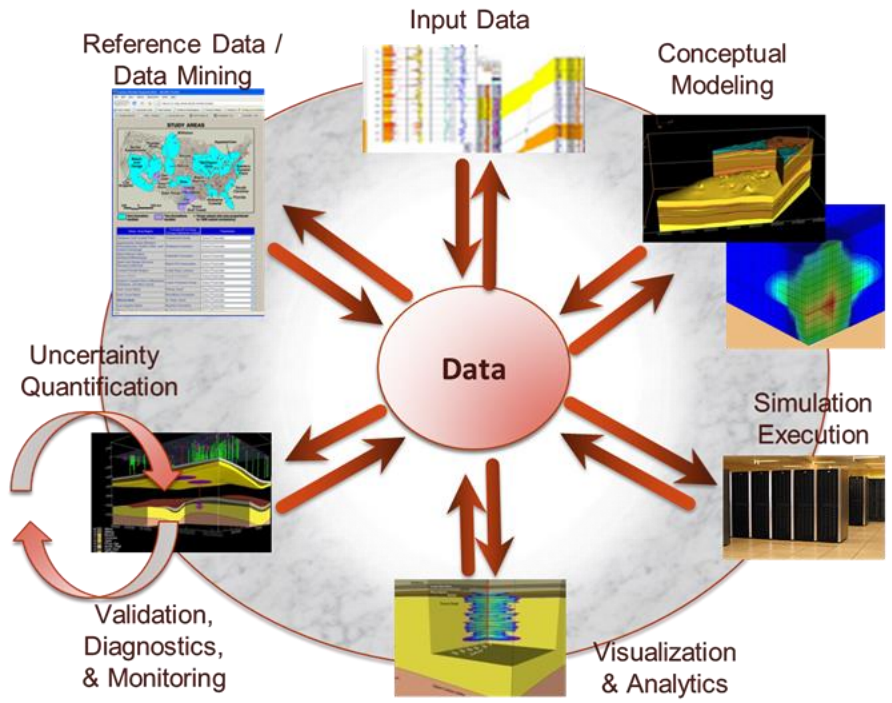
$44 of profits/cost savings per dollar of HPC invested

2016 update: http://www.hpcuserforum.com/ROI

HPC4Subsurface
Possible applications

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

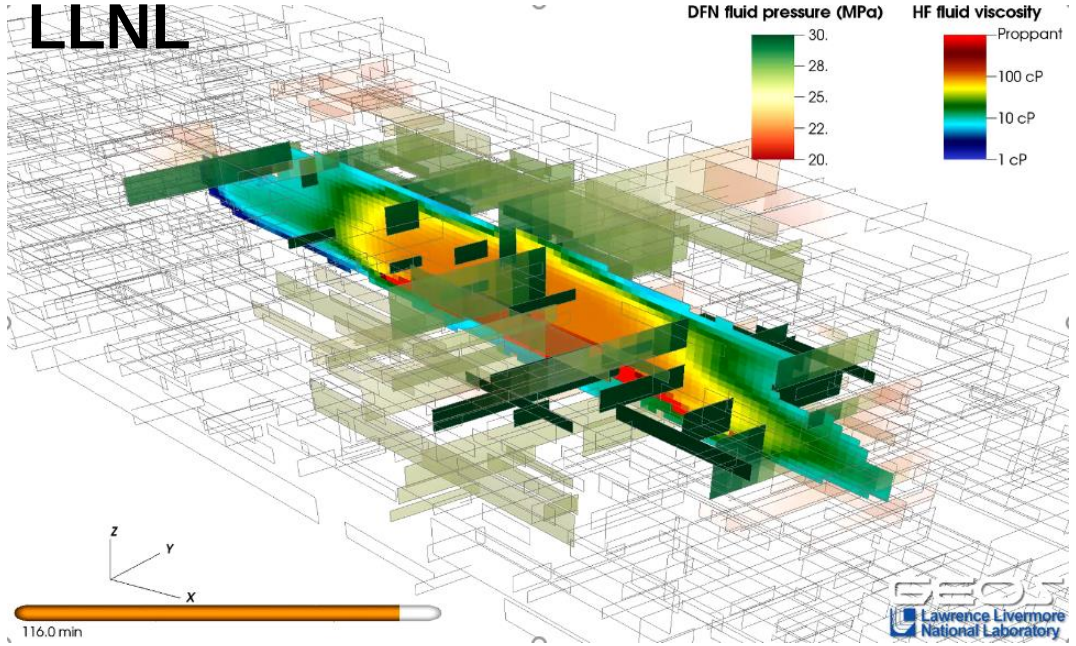
- Provide **timely, actionable intelligence** for reservoir engineering and management
  - **On-the-fly synthesis of realtime operational data** with existing data and reservoir models
  - **Immediate feedback** on reservoir response
  - Integrated machine learning and predictive science to **refine the underlying models**
  - **Improved efficiency** and **reduced costs** for both exploration and production
  - Applications in **O&G, CCS and geothermal** industries
- Develop and deploy **tools to facilitate ML** across multiple disparate formats and resolutions for products unique to subsurface exploration and development (e.g., well logs, seismic lines, real-time operational metrics, microseismic)
- Enable **deep analysis of massive data volumes** across wells / fields / reservoirs / lithologies to investigate subtle effects that might not be resolved via conventional methods

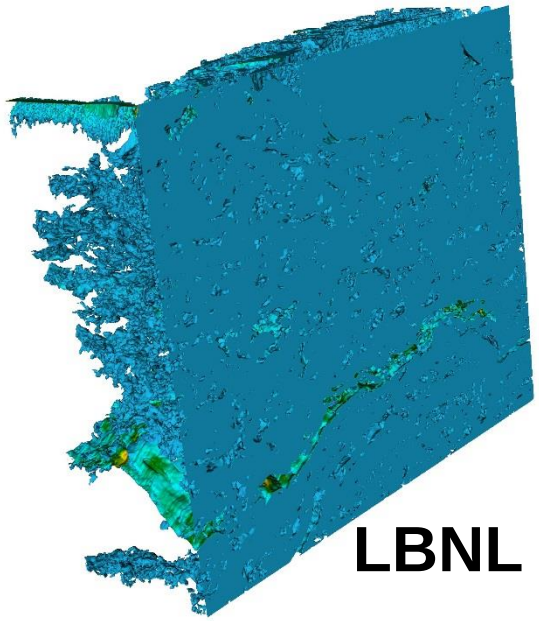


VG Courtesy Casie Davidson, PNNL

DOE uses HPC to understand unconventionals at multiple scales

- Field scale studies indicate inherently ***3D*** interactions among hydraulic fractures, stress barriers, and preexisting natural fractures in shale plays



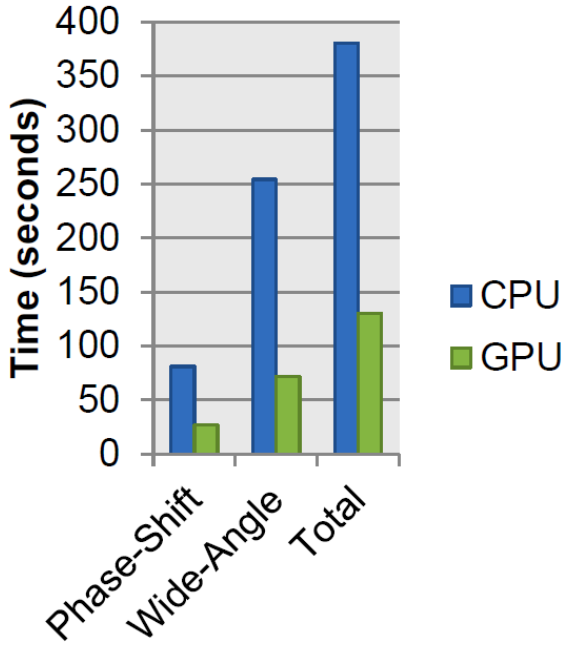


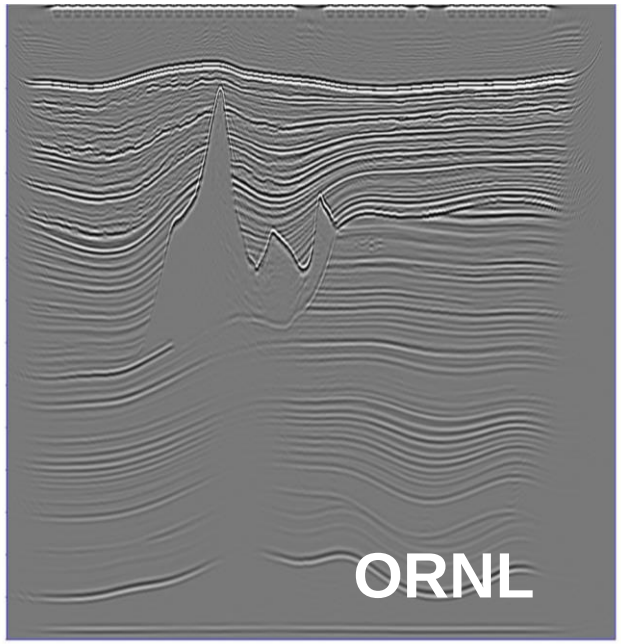
- First-ever computer simulations of fully resolved flow in fractured shale from FIB-SEM data of rock samples (100 Billion degrees of freedom)

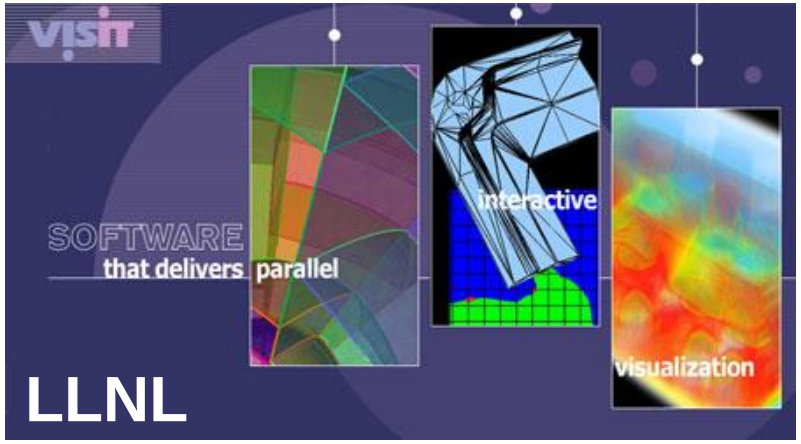
Part of ECP

Reservoir Management: Huge Datasets for Inversion/Visualization

- Working with industry to exploit HPC for rapid, accurate seismic inversion
- Exploring novel algorithms on emerging hardware







- Creative processing and visualization to get the most of data and models

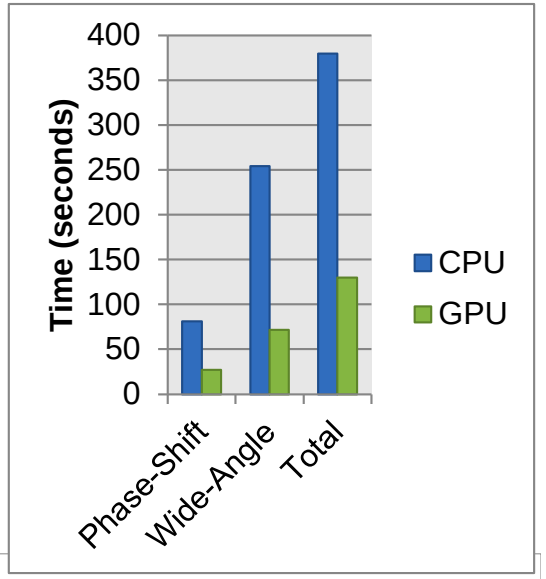
CRADA: Seismic Depth Imaging at Scale

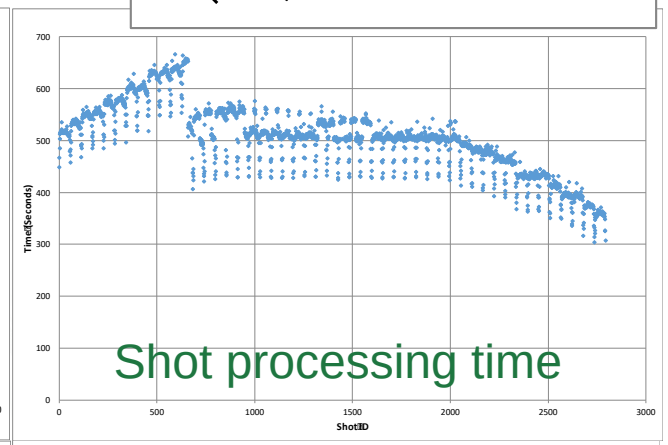
- **Goals**
  - *CRADA Partner*: Explore use of GPU accelerators and scaling issues for shot profile migration
  - *OLCF*: Inform design/implementation of languages supporting GPU offload (OpenACC, OpenMP), I/O libraries, etc.

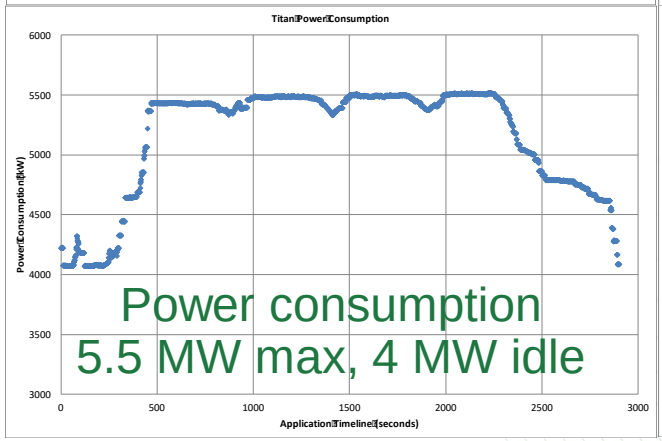
- **Accomplishments to Date**
  - Achieved ~3x speedup on One-Way Wave Equation Migration (single node)
    - 1 NVIDIA K20x GPU (Titan) vs 1x 8-core Intel Sandy Bridge CPU
  - Processed 2800 shot data set in full-system run on Titan (18,688 nodes; 27 PF peak)
    - First known real-world application run at large scale using OpenACC
    - Achieved 1.2 PF peak performance using 5.5 MW power
  - Applied lessons learned to Reverse Time Migration

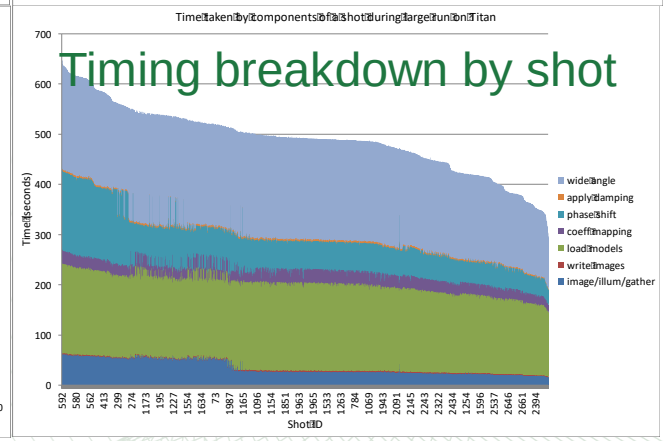
VG courtesy Yoram Polsky, ORNL

OAK RIDGE National Laboratory | LEADERSHIP COMPUTING FACILITY

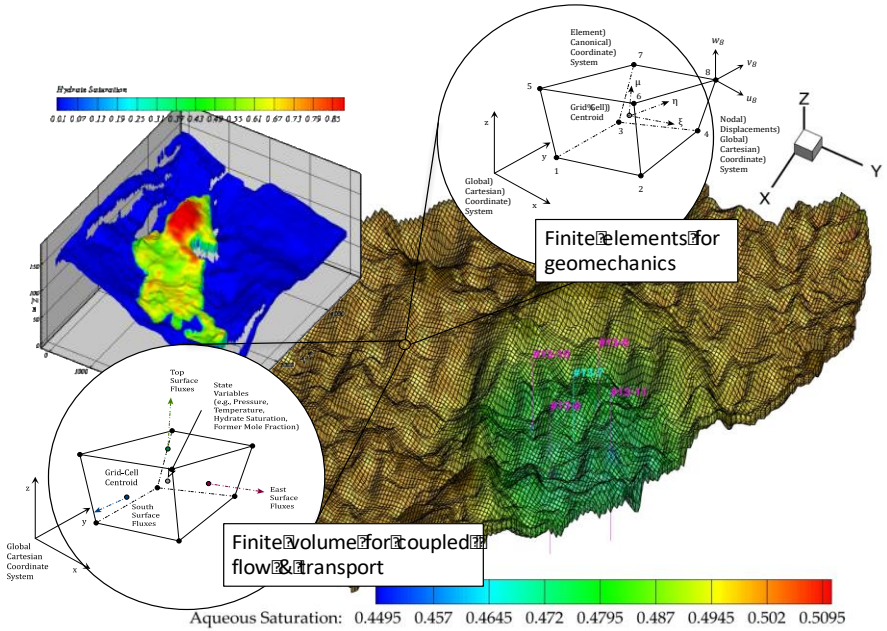




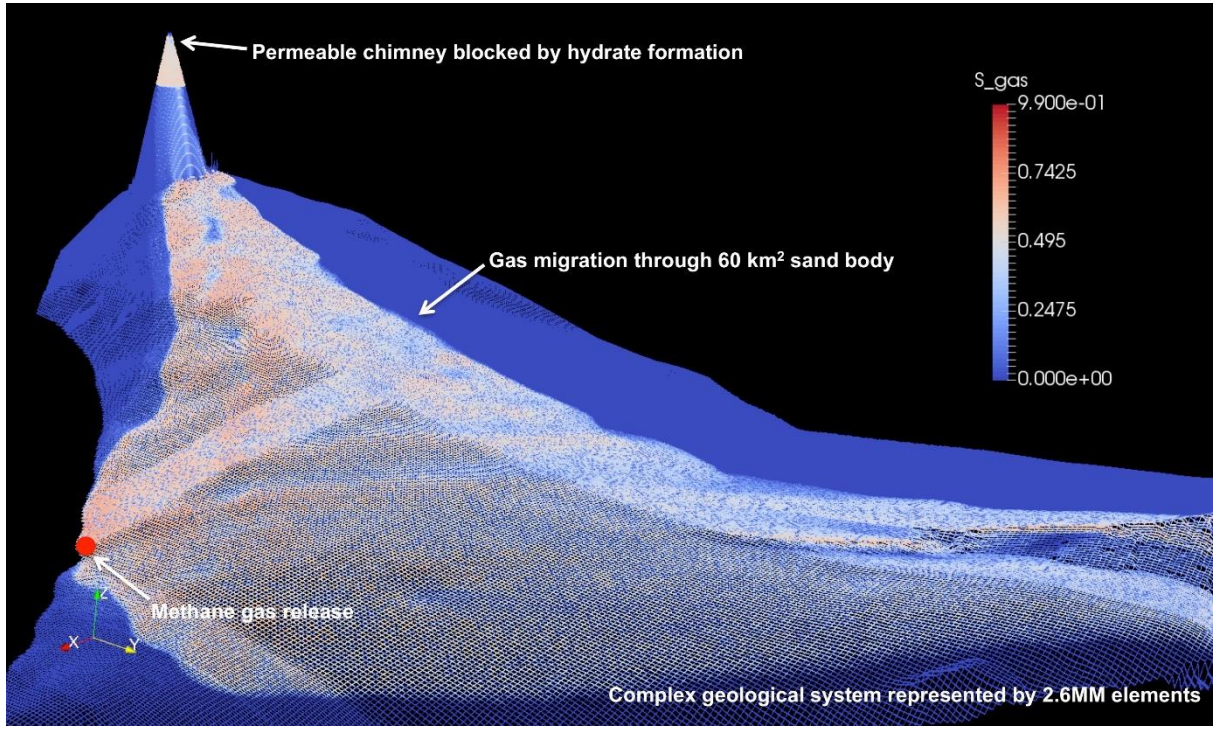




Gas Hydrate Reservoir Simulations with Coupled Geomechanics



- Multiple complex processes, modeled at multiple time- and length scales (cm to km, seconds to years)
- Coupled geomechanics essential
- **Tens of millions** of grid cells
- Inherent uncertainties → many realizations
- Tens of thousands of CPU hours per realization
- Need **large-scale high-performance computing (HPC)** specifically for FE applications
- Need for **large scale, real-time visualization**



VG courtesy Tim Kneafsey and Matt Reagan, LBNL

Summary and Discussion

HPC is expanding from the realm of scientific discovery (the lab) to the factory, power plant & shop floor.

HPC models of energy systems can reveal cost savings & deliver confidence in design changes.

HPC is not just simulation. HPC data analytics, e.g. from sensor networks can inform operation of energy systems.

Above: Lowering the risk of HPC adoption in industry.
Below: NERSC's Cori system advances time-to-solution.

The HPC "app store" is growing: materials genomics, turbines, furnaces, metals, PV, batteries, & SUBSURFACE!

HPC software used in discovery science can be re-purposed to solve applied problems. Open source.

HPC algorithms deliver game changing speed-ups. Can change how we think about models. Digital twins, e.g.

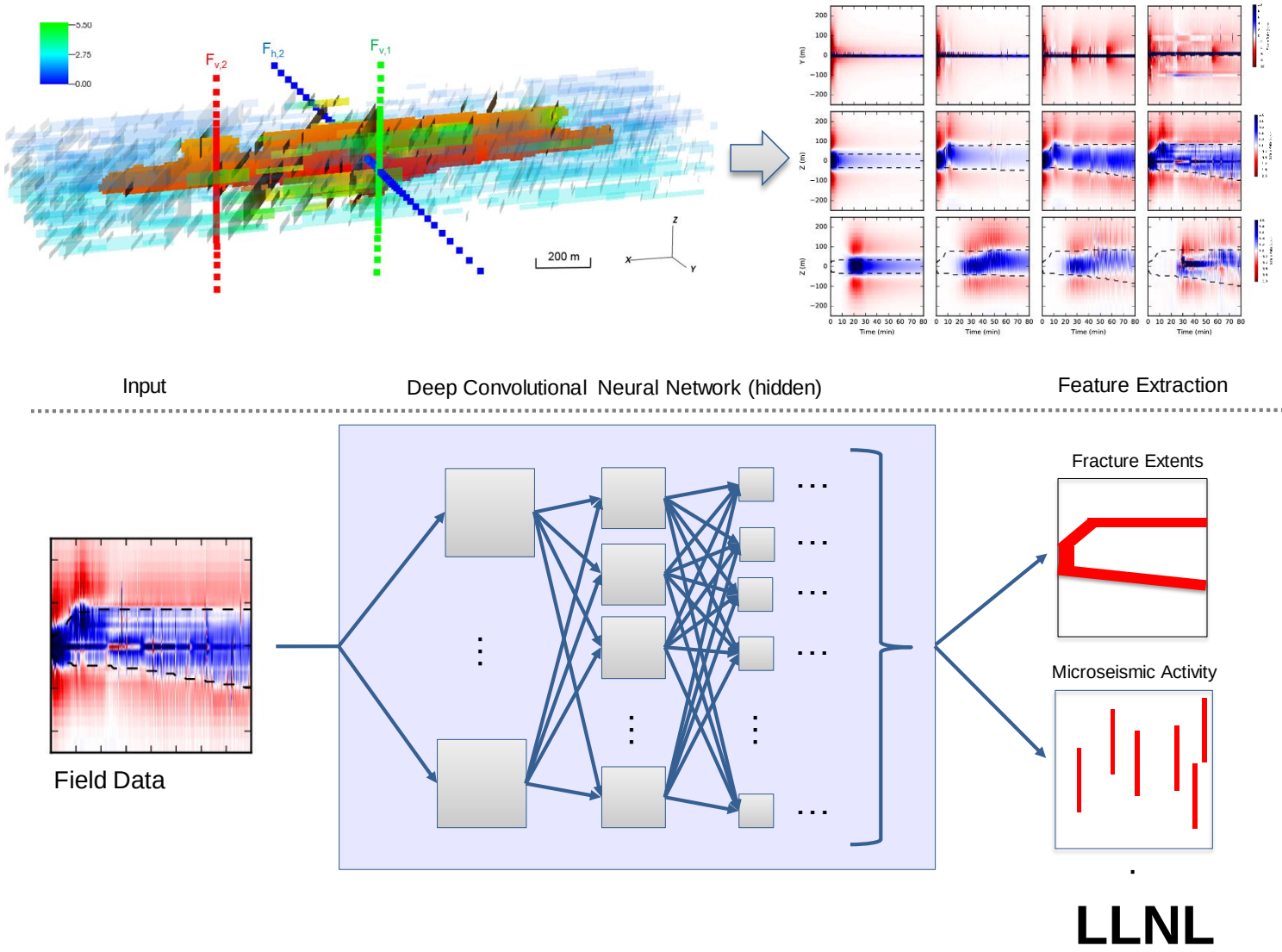
VG courtesy David Skinner, LBNL

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

DOE is Engaged in HPC-Enabled Big Data Efforts

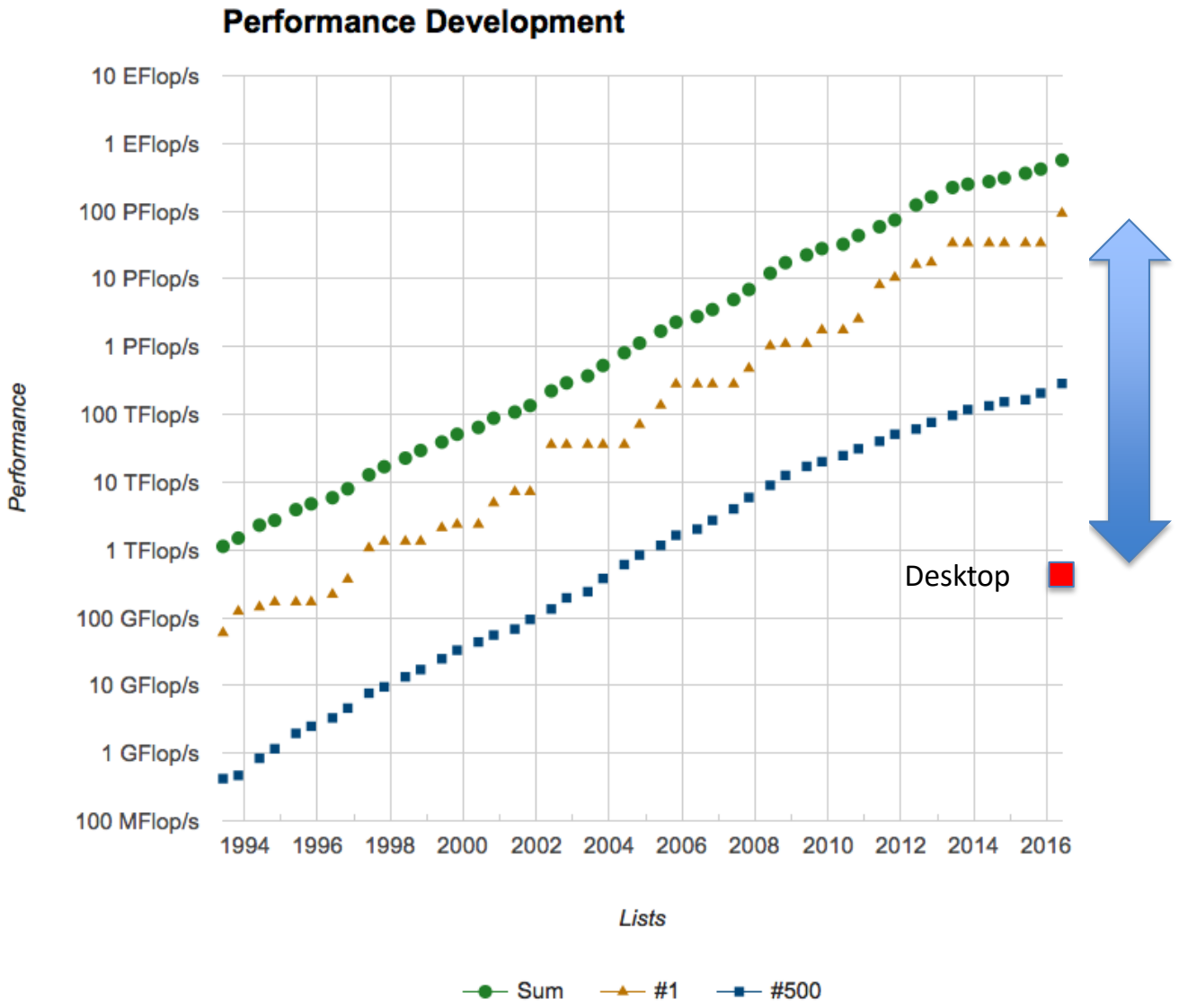
- Use HPC to generate millions of synthetic DAS measurements (Dist. Acoustic Sensing)
- Design and train a deep convolutional neural network (DCNN) to identify features
- Optimize the DCNN and test it on field data

Capability could be used to make pumping schedule changes in real time during stimulation to target pay zone more effectively



LLNL

High performance computing offers an opportunity



Current supercomputers are **5+ orders of magnitude** more powerful than desktop computing

Can we apply this capability to industrial problems?

The Program has had significant engagement from a diverse industry through 4 solicitations

- **Diverse technical portfolio**
  - Executing on ~50 projects with 30 industry partners and 6 labs
  - Offices: Advanced Manufacturing, Vehicles Technology, Fossil Energy, Office of Science
- **Fall 2017 Solicitation recently concluded**
- **2018 Solicitation underway**
- **Key benefit** is a direct link to SMEs at each lab—knowledgeable POCs who direct companies to the right group and guide the statement of work.

Bridging the gap between U.S. Manufacturers and national labs with public-private partnerships

FEDBIZOPPS.GOV Federal Business Opportunities

Engage industry

Industry submits challenges

Match challenge to PI

AMO approval; Feedback to industry

Sign agreements

Inform industry

Concept paper → Full proposal → Award

Technical Review Committee

Technical Merit Review Committee

- Partner labs and AMO representatives
- Heavy focus on **nation-wide** impact to energy efficiency and clean energy technology industry-wide

Execution streamlined through the required use of the DOE short form—An easy way for industry to engage the national lab's HPC expertise at low risk.

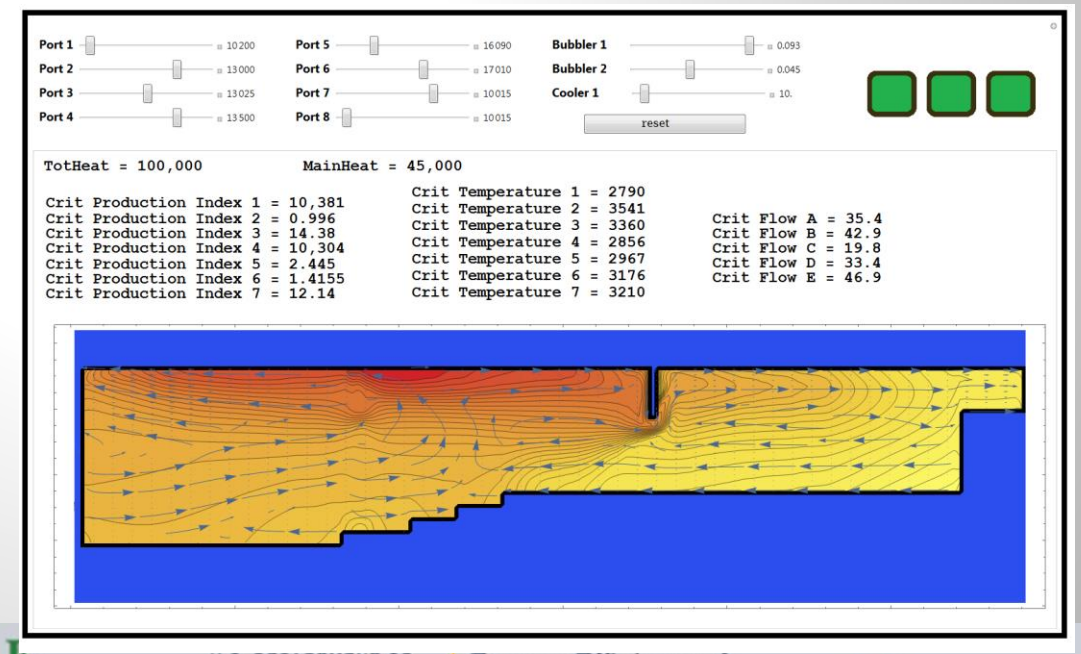
Vitro Glass—Energy intensive manufacturing

- **Need:** Optimized process operation and production in glass making
- **Approach:** Apply fully validated fluid model for a parameterization study; statistic analysis; machine learning
- **Outcome:** A reduced-order glass furnace model—plant engineers now make informed, real-time process adjustments.

Dr. Victor Castillo—LLNL PI

Impact:

- **Save ~two weeks of production per year per furnace**
- **Increase productivity by 2%**
- **Industry wide (U.S.): Save ~2.5 TBTUs of energy and avoid 130,000 metric tons of carbon dioxide emissions**



GUI aids visualization and decision making

Questions?

Additional information at HPC4Mfg.org

Questions can be sent to HPC4Mfg@llnl.gov

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